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ABSTRACT

This combined student workbook and instructor's guide contains nine units for inplant classes on basic chemistry for employees in the cement industry. The nine units cover the following topics: chemical basics; measurement; history of cement; atoms; bonding and chemical formulas; solids, liquids, and gases; chemistry of Portland cement manufacture; control, analysis, and testing; and organic chemistry and fuels. Unit objectives, tests, and answer keys are included in the book. (KC)

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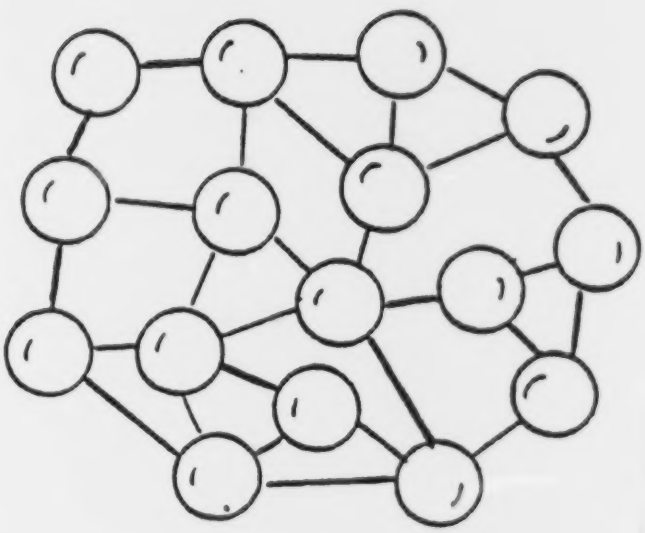
ED 379 512

BASIC CHEMISTRY

FOR

THE CEMENT INDUSTRY



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CE 068 367

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This is a basic course for Holnam, Inc., a producer of PORTLAND cement. The purpose is to teach employees without a chemical background elementary chemical concepts so they may have a better understanding of the processes used in the production of PORTLAND cement. This course should give them an appreciation of the importance of chemistry in the PORTLAND cement making process from the time the limestone and clay leave the quarry, until the finished product leaves the plant.

Mason Turner
1994

"The contents of this curriculum were developed under a grant from the Department of Education. However, those contents do not necessarily represent the policy of the Department of Education, and you should not assume endorsement by the Federal Government."

TEACHER NOTES

Please note the following listed materials or plant tours needed to complete the following applications.

I. Chemical Basics

Atom Model Kit, or Styrofoam balls.

II. Measurement

Application 5.

metric sticks, metric rulers, graduated containers, thermometers

VI. Solids, Liquids and Gases

Application 3. p. 32

Need Molecular Motion Device and O.H. Projector.

Application 6, 7 and 8. p. 35

Mix clay with water.
Mix powdered sugar with water.
Mix and shake oil with water.

VII. Chemistry of Portland Cement Manufacture

Need copies of Holnam publication: "Helping Build Our Future" for each student.

VII. Chemistry of Portland Cement Manufacture

Application 7. p. 43

Mix sand and cement in a plastic cup.

Application 8.

Pencil, thermometer

VIII. Control, Analysis and Testing

Application 4. p. 48

Need printouts of cement analyses from the XFS. Tour of XFS in laboratory.

Application 5. p. 49

Visit the crystallography room of the lab and look at clinker samples through a microscope.
Visit lab. See how tests listed in Application 6 are run.

IX. Organic Chemistry, Fuels

Application 4. p. 55

Styrofoam needed for models.

Application 5. p. 57

Need CRC Handbook of Chemistry and Physics or Lange's Handbook of Chemistry.

Application 6. **p. 58**

Encyclopedias for petroleum (how coal and oil form)

Application 9. **p. 60**

Tour Safety Kleen lab.

Periodic Table of Elements

	1A	2A										3A	4A	5A	6A	7A	0
1	1 H 1.00		**Metals**									**Nonmetals**					2 He 4.00
2	3 Li 6.94	4 Be 9.01										5 B 10.8	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.0	10 Ne 20.2
3	11 Na 23.0	12 Mg 24.3										13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.5	18 Ar 39.9
4	19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.8	27 Co 58.9	28 Ni 58.7	29 Cu 63.5	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
5	37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc (99)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	57-71 *See Below*	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (210)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89-103 *See Below*	104 Ku?	105 Ha?													

Lanthanides	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (147)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
Actinides	89 Ac (227)	90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (249)	98 Cf (251)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (254)	103 Lr (257)

Numbers in parentheses are the mass numbers of the most stable or best known isotopes for elements which do not occur naturally.

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Atomic Weights (Masses) of the Elements

Element	Symbol	Atomic No.	Atomic Wt.
Actinium	Ac	89	(227)
Aluminum	Al	13	26.9815
Americium	Am	95	(243)
Antimony	Sb	51	121.75
Argon	Ar	18	39.948
Arsenic	As	33	74.9216
Astatine	At	85	(210)
Barium	Ba	56	137.34
Berkelium	Bk	97	(249)
Beryllium	Be	4	9.0122
Bismuth	Bi	83	208.980
Boron	B	5	10.811
Bromine	Br	35	79.904
Cadmium	Cd	48	112.40
Calcium	Ca	20	40.08
Californium	Cf	98	(251)
Carbon	C	6	12.01115
Cerium	Ce	58	140.12
Cesium	Cs	55	132.905
Chlorine	Cl	17	35.453
Chromium	Cr	24	51.996
Cobalt	Co	27	58.9332
Copper	Cu	29	63.546
Curium	Cm	96	(247)
Dysprosium	Dy	66	162.50
Einsteinium	Es	99	(254)
Erbium	Er	68	167.26
Europium	Eu	63	151.96
Fermium	Fm	100	(253)
Fluorine	F	9	18.9984
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.72
Germanium	Ge	32	72.59
Gold	Au	79	196.967
Hafnium	Hf	72	178.49
Helium	He	2	4.0026
Holmium	Ho	67	164.930
Hydrogen	H	1	1.00797
Indium	In	49	114.82
Iodine	I	53	126.9044
Iridium	Ir	77	192.2
Iron	Fe	26	55.847
Krypton	Kr	36	83.80
Lanthanum	La	57	138.91
Lawrencium	Lr	103	(257)
Lead	Pb	82	207.19
Lithium	Li	3	6.939
Lutetium	Lu	71	174.97
Magnesium	Mg	12	24.312
Manganese	Mn	25	54.9380
Mendelevium	Md	101	(256)
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.94
Neodymium	Nd	60	144.24
Neon	Ne	10	20.183
Neptunium	Np	93	(237)
Nickel	Ni	28	58.71
Niobium	Nb	41	92.906
Nitrogen	N	7	14.0067
Nobelium	No	102	(254)
Osmium	Os	76	190.2
Oxygen	O	8	15.9994
Palladium	Pd	46	106.4
Phosphorus	P	15	30.9738
Platinum	Pt	78	195.09
Plutonium	Pu	94	(242)
Polonium	Po	84	(210)
Potassium	K	19	39.102
Praseodymium	Pr	59	140.907
Promethium	Pm	61	(147)
Protactinium	Pa	91	(231)
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.905
Rubidium	Rb	37	85.47
Ruthenium	Ru	44	101.07
Samarium	Sm	62	150.35
Scandium	Sc	21	44.956
Selenium	Se	34	78.96
Silicon	Si	14	28.086
Silver	Ag	47	107.868
Sodium	Na	11	22.9898
Strontium	Sr	38	87.62
Sulfur	S	16	32.064
Tantalum	Ta	73	180.948
Technetium	Tc	43	(99)
Tellurium	Te	52	127.60
Terbium	Tb	65	158.924
Thallium	Tl	81	204.37
Thorium	Th	90	232.038
Thulium	Tm	69	168.934
Tin	Sn	50	118.69
Titanium	Ti	22	47.90
Tungsten	W	74	183.85
Uranium	U	92	238.03
Vanadium	V	23	50.942
Xenon	Xe	54	131.30
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.905
Zinc	Zn	30	65.37
Zirconium	Zr	40	91.22

Based on mass of C^{12} at 12.000. Values in parentheses are the mass numbers of the most stable or best known isotopes for elements which do not occur naturally.

Section I Objectives

1. Be able to identify a material as compound or mixture, given sufficient information about that material.

2. Be able to distinguish between a chemical and physical change, given sufficient information about the change.

3. Be able to decide which properties are chemical and which are physical properties.

4. Be able to set up a classification scheme for a collection of items.

5. Be able to describe a useful model system in chemistry.

I. Chemical Basics

A. Elements, Compounds, and Mixtures

Any matter found in nature can be classed as either an element, compound, or mixture.

1. Elements: Simple substances that are made up of only 1 kind of atom.

There are only 109 known elements that have been discovered to date. Even the rocks brought back from the moon by the astronauts were found to contain no new elements. We believe that all matter in the universe is made up of these 109 elements. An alphabetical list of these elements and their symbols are at the beginning of your book. Also, you will see there a Periodic Table. This is a special arrangement of all these elements according to their behavior. Notice in this Periodic Table that there are two main classes of elements: metals and nonmetals. Notice also that a few are gases, only 2 are liquids (Bromine and Mercury), and most are solids.

Application 1.

1. *Go through the alphabetical list of the elements in the front of your book. Decide which items around your house and at Holnam contain some of these elements, and make a list of them.*
2. *Look at your list and put an M beside the ones you think are metallic elements.*
3. *Then look at the Periodic Table in the front and see if you agree which elements are metals, and which are nonmetals. Can you explain any differences between your list and the Periodic Table? (Hint: Look ahead to the next section.)*

As you noticed in the list of elements, elements can either be named, or represented by their symbols. Here are the symbols of some elements important in Cement Manufacture: Ca, Mg, Al, O, Si, C, H, Fe, K, Na. Can you tell each of their names? Notice that all but the last three of these start with the same 1 or 2 letters as the name of the element. Fe comes from the Latin name for this element.

2. Compounds and Mixtures

Combination of elements make compounds and mixtures. Most natural materials are mixtures, many are compounds, but only a few (109) are free, (uncombined or

unmixed) elements. For example, air is a mixture of about 20 percent oxygen, 78 percent nitrogen, 1 percent argon, and small amounts of carbon dioxide, water vapor, and other gases. Nitrogen, oxygen, carbon dioxide, and carbon monoxide are very important for control of combustion within the kilns.

Definitions:

Molecule: A small unit of matter usually made up of more than 1 atom chemically bonded together. Examples: O_2, H_20, NH_3 (ammonia), S_8 (sulfur), CO_2, C_3H_8 (propane), CH_4 (methane or natural gas).

Compound: A substance made up of 2 or more elements. Their atoms are chemically bonded together, usually in set proportions. The elements behave differently in the compound than as the free elements. Example: the flammable free element hydrogen (H_2) and the active element oxygen (O_2) combine to make the compound water (H_2O), which is used to put out fires and cannot be breathed.

Mixture: Two or more substances mixed together, but not chemically joined. Proportions of the substances can be varied, and the substances retain most of their characteristics in the mixture. Example: Methyl red dye in varying amounts will dissolve in alcohol to make a lighter or darker red solution. Example: Oil when shaken with water will mix temporarily, but separate on standing. Example: Water mixes with alcohol, but doesn't separate on standing.

Application 2.

Now go back to your list of sources of elements (Application 1) and decide if some of your items in the list were probably compounds or mixtures. If you think so, put a comp. or mixt. beside it. (Note: Even chemists sometimes have trouble making such decisions. They often have to make many laboratory tests to decide whether a material is an element, compound, or mixture.)

Application 3.

Make a further list of materials around your house and around the plant, and try to identify them as compounds or mixtures. (Note: Most materials are mixtures. Most liquids are solutions (mixtures) of a substance dissolved in a solvent.)

B. Chemical and Physical Changes

Chemical Change: A change in which new substances are produced, because chemical bonds are broken and/or formed.

Physical Change: A change in which no new substances are produced (no bonds broken and/or formed).

Application 4.
Decide whether you think the following are chemical or physical changes (or both):

a. *Digestion of food.*
b. *Making the slurry.*
c. *Burning coal.*
d. *Changes in the plant kilns to make clinker from slurry.*

C. Properties: Chemical and Physical

Chemical Properties: Behavior characteristics of a material based on how it can change chemically.

Physical Properties: Behavior characteristics based on how a material can act without changing chemically.

Application 5.
Decide whether each of the following is a chemical or physical property of a material:

hardness, melting point, corrosion capability, color, combustibility, reactivity toward chlorine, boiling point, compression strength

D. Classification Systems in Chemistry

Using classification (or grouping) schemes to organize information is one common-sense way to deal with new or not-well-understood situations. All of us use these grouping techniques automatically to deal with our surroundings. For example, we automatically group our household expenses into categories like food, clothing, housing, transportation, etc. Materials at Holnam can be grouped as raw materials, finished products, fuels, wastes.

Application 6.
(a) Develop a grouping system for all the furniture in your home. Write down the groups (class) names, and list individual items of furniture belonging under each group.
(b) Does any item of furniture fit in more than one group (overlap)? If so, state it.
(c) Can you develop another, different grouping system for your furniture? If so, write down the group names for this system.

Chemists often use grouping systems to simplify dealing with the many kinds of matter and changes they study.

Application 7.
Look back over the previous sections and see how many different grouping systems you can spot. Write them down.

E. Model Systems

Story of the Elephant and the 4 blind men

One day 4 blind men came upon an elephant, and they were trying to decide what it was. One blind man said it was like a tree, another said it was like a rope, another said a wall. The fourth said "No, it's a pick-axe".

Application 8.
Why did they say what they did? Who was right?

This story illustrates making a model system to explain something puzzling. Each blind man created a different model (rope, wall, tree, pick-axe) to explain what he felt.

In like manner, scientists create and use model systems to explain puzzling situations. Two important such scientific models we will use are the atomic-molecular model for matter and the heat flow model for heat energy.

The heat flow model says that heat moves (flows) from a material with a higher temperature to one with a lower temperature like water flows from a higher to a lower elevation. This model help us understand how the chains in the kiln operate to

transfer heat to the slurry.

The atomic-molecular (or particle) model for matter says that all matter is made up of extremely small bead-like particles called atoms. These atoms bond (hook) together in various patterns to make molecules.

As we will see, we can explain much of what is happening around us and in the making and using cement by using this particle model for matter.

Indeed, as you have probably noticed, we have already been using this atomic-molecular model system (theory) to begin explaining materials and processes going on around us. (Look back and see definitions for elements and compounds in this section).

Section II Objectives

1. Be able to tell why a knowledge of the metric system is important at Holnam.

2. Be able to estimate metric volumes, mass, lengths or degrees Celsius for given examples.

II. Measurement

Like good detectives, scientists keep their eyes and ears open to observe what is going on around them. This trait is equally important for cement plant employees. Careful observation can spot many problems before they become major, and result in smoother operation and a better finished product.

Many observations that are made don't require knowing amounts (like color, odor, etc.). Many plant operations, however, do require measurements to be made.

Application 1.
List plant operations where measurements are necessary, and tell what is measured.

Although here in the United States, we grow up learning the so-called English system of measurement, most people around the world (as well as all scientists) use the Metric System. Our country is slowly changing. For example, large bottles of soft drinks are measured in what volume units now? Since Holnam deals with countries around the world, a knowledge of the Metric System is important.

Application 2.
Check the labels of a number of boxes, bottles, and cans at home, and make a list of the measuring units on them. Circle any metric units.

The four main metric measuring units are:

1. meter (m) for length [1 meter is a little bit longer (about 10% longer than a yard)]
2. gram (g) for mass (mass is related to weight) (a gram is a small amount of mass about equal to a regular paper clip's mass)
3. liter (l) for volume (1 liter is a little larger (about 5% more) than 1 quart)
4. Celsius scale (°C) for temperature

	Celsius	Fahrenheit
Freezing pt. of water	0°	32°
Room temperature	24°	75°
Boiling pt. of water	100°	212°

Larger and Smaller Metric Units

Different sized English system length units are given different names (inch, foot, yard, mile). However, the metric system uses a set of prefixes to create smaller and larger length units. The most used of these prefixes are:

smaller units	milli means the 1/1000 part of centi means the 1/100 part of deci means the 1/10 part of
larger units	kilo means 1000 units of

So, the metric length units are millimeter, centimeter, decimeter, meter, kilometer (mm, cm, dm, m, km). Likewise, these prefixes are used in front of the other metric units of mass and volume.

Remember: (1) prefixes ending in "i" make smaller sized measurement units.
(2) It takes fewer larger sized units of a material to equal more smaller sized units of that material

Example: $\underline{1000}$ mm = $\underline{1}$ m

1000	mm	=	1	m
larger number	smaller sized unit		smaller number	larger sized unit

The more you use the metric system for measuring, the more natural it becomes. As a starter, try estimating the following metric amounts, using the hints given:

Application 3.
Estimate (make a good guess) in <u>metric</u> units.
1. The volume of gasoline it takes to fill your car's gas tank (1 liter is about 1 quart)
2. The thickness of a pencil shaft (1 mm is about the thickness of a dime.)
3. The length of a new pencil (1 cm is about the <u>width</u> of your little finger).

4. Your mass (weight). (1kg is about 2 pounds)
5. The speed limit on the interstate in kilometers per hour (a mile is a little more than one and a half kilometer).
6. The temperature of the kiln at the end where the finished clinker comes out is about 3000°F. Estimate this in °C. (At higher temperatures 1 Celsius degree is about equal to 2 Fahrenheit degrees).
7. The mass (weight) of a tablespoon of salt (a nickel weighs about 5 grams).
8. The volume of a teaspoon of cough syrup (an eyedropper holds about 1/2 ml of liquid).
9. Normal body temperature (average room temperature is about 75°F which is about 25°C)
10. The mass of a bag of cement (1 kg is about 2 pounds)
11. The volume of an iced tea glass (1 qt is about 1 liter, which is 1000 ml).
12. The mass (weight) of a medium-sized sirloin steak (1 lb. is about 500 grams, or 1 oz. is about 30 grams.

Application 3b.
Use the following table to calculate more accurate estimates for your answers in Application 3.

Table 1:

1 liter	=	1.1 quarts
1 inch	=	2.5 cm
1 kg	=	2.2 lbs
1 mile	=	1.6 km
1 lb	=	454 g
1 oz	=	28.3 g
°C	=	5/9 (°F - 32)
°F	=	9/5 °C + 32

Often, estimating amounts gives results which are close enough to go by. This is often true in cooking, for example. The key, however, is knowing when accurate measurements must be made. In cement manufacturing, many amounts must be measured accurately using appropriate instruments. A partial list of measuring instruments is given below:

length:	meter sticks, micrometer caliper, length comparators
mass:	scales, balances, analytical balances
volume:	graduated containers, pipettes, burettes
temperature:	thermometers, thermocouples, thermistors, optical pyrometers

Application 4.

Estimate the following metric amounts (use the hints and table given in the previous application).

1. *The length, width, thickness, and mass of this manual.*
2. *The volume of a styrofoam coffee cup.*
3. *The mass of a quarter, a dollar bill.*
4. *The current outdoor temperature.*
5. *The distance from here to Charleston.*
6. *The average daily mass of cement manufactured at Holnam (1 metric ton = 1000 kg).*
7. *The volume of air in this room (1 cubic meter is also called a stere).*

Application 5.

Using metric sticks, metric rulers, graduated containers, and thermometers, measure as many of the items in the previous examples as possible, and compare them to your estimates.

Section III Objectives

1. Be able to briefly describe the production and use of cement in Ancient Egypt and Rome.

2. Be able to tell the chief components of Portland Cement and the conditions required to produce it.

3. Be able to tell what a hydraulic cement is.

4. Be able to describe the difference between cement and concrete.

III. History of Cement

A. Cements in Ancient Times

No one knows when cementing materials were first discovered. It was probably soon after prehistoric man learned to control and use fire. If he had built a fire on limestone (mostly $CaCO_3$) or gypsum rocks (mostly $CaSO_4 \bullet 2H_2O$), fire would have caused part of the rocks to change chemically and crumble to a powder. If rain had fallen on this powder, possibly mixed with sand or gravel, a further chemical change would have occurred resulting in a crude form of stone masonry.

The ancient Egyptians used a calcined (heated) impure gypsum to produce a grouting or mortar to hold together blocks of stone in their pyramids and buildings. Later, the Greeks and Romans used calcined limestone mixed with water. More often, they used calcined limestone mixed with water, sand, and gravel (or crushed tile or brick) to make an early form of concrete. (This is still used today in wall board and plaster.)

Application 1.
Mix some plaster of Paris (calcined gypsum) with water to make a paste and let it set up in a plastic cup. Then tear off the cup and check some of the properties of the sample you made (hardness, brittleness, color, odor, resistance to heat, etc.)

Chemical Equation for setting of Plastic of Paris:

$CaSO_4 \bullet 1/2\ H_2O + 1\ 1/2\ H_2O \rightarrow CaSO_4 \bullet 2H_2O$

plaster of paris + water --> gypsum

The Romans were probably the first to notice that the more finely they ground the heated limestone, and the better they mixed and pounded (packed) the concrete as it set, the stronger and longer lasting product they obtained. They also found that the addition of certain volcanic sands allowed the mixture to harden even under water. (A cement that will harden under water is called a "hydraulic" cement.) Today, we use fly ash for the same reason.

B. Cement in Modern Times

Although a number of people contributed to its development, Joseph Aspdin in 1824 first patented a product that he called Portland Cement. He found that it was necessary

to add a certain amount of clay to the limestone before firing to obtain a strong and durable product.

The cement industry in the United States developed in the early 1800's as a result of the need for large amounts of hydraulic cement to build canals. Large deposits of rock such as the cement rock found in the Lehigh Valley in Pennsylvania were found to have good cement-making qualities after calcining. As better grades of cement became available, more and more cement was produced and used for roads, sidewalks, buildings and bridges. By the end of the 1890's, cement manufacture was a major industry in this country. Since this time the cement industry has steadily improved its understanding of the proper proportions of ingredients, temperature of calcining, and required fineness of grinding needed to produce a superior product. Increased understanding of the chemical structure of cement and the chemical and physical changes occurring during its manufacture and use continue to be made.

C. The Keys to Portland Cement Manufacturer

Portland cement is a product gotten by finely grinding and thoroughly mixing together limestone (mainly $CaCO_3$), and clay and fly ash (mainly Al, Si, Fe, and O compounds). Iron oxide may also be added. This mixture is then fired at a high enough temperature to partially melt the mixture and produce a clinker. Before using, this clinker is ground to a very fine powder. Careful control of the proportions, grinding, mixing, and firing temperatures are essential in the process. The resulting cement produces concrete with high strength, controlled setting times, ability to harden under water and good weathering properties.

Application 2.
List examples of cement use where:
(a) strength is important
(b) setting times need to be controlled

Section IV Objectives

1. Be able to name the 3 particles that make-up atoms, and tell their charge, relative mass, and position in the atoms.

2. Be able to diagram an atom of any element, given its atomic number. This simplified diagram should show the number of protons in the nucleus and the total number of electrons outside the nucleus.

3. Be able to diagram an atom of elements 1-36, given its atomic number. This diagram should show the Bohr shell arrangement for the electrons.

4. Be able to explain the importance of the numbers 2 and 8 in terms of an element's stability.

IV. Make Up of Atoms of the Elements

A. Introduction

We have learned that an element is a simple substance whose atoms are all alike. But that makes the atoms of one element different from the atoms of other elements? Scientists have good reasons for believing that the insides of the atom provide the clue to explain this question.

B. Protons, Electrons, and Neutrons in atoms.

Scientists believe that atoms themselves are made up of still smaller particles called electrons, protons, and neutrons. They are arranged in an atom something like the sun and planets in our solar system, except on a tiny scale.

Table 2:

Table of Sub-Atomic Particles:

	electrical charge	mass*	position in the atom
proton	+1	about 1	in center of atom
neutron	0	about 1	in center of atom
electron	-1	about 1/2000	outside the center

(*Note: Hydrogen, which is the lightest atom of all has a mass of about 1 on this scale.)

From the table you can see that atoms are made up of protons and neutrons in the center of each atom, with electrons outside the center. The center of the atom is called its nucleus.

Electrical charges attract or repel each other according to the rule: like charges repel, unlike charges attract. The attraction and repulsion of electric charges is something like

the way the N and S poles of magnets behave toward each other.

Application 1.

(a) The nucleus of an atom has what kind of charge (positive or negative)?

(b) Where is most of the mass of an atom (in the nucleus, or outside the nucleus)?

Now we can explain in what way that atoms of a certain element are all alike: Each atom of a certain element has the same number of protons (the same positive charge on the nucleus). Example: all calcium atoms contain 20 protons. Likewise, different elements' atoms have different numbers of protons. Example: Calcium atoms have 20 protons, but oxygen atoms have 8 protons.

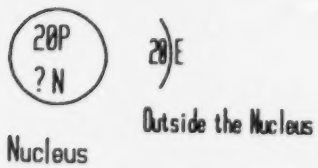
Based on much effort and many experiments, scientists have figured out how many protons are in the atoms of all 109 known elements. In the Periodic Table, the elements are arranged according to how many protons their atoms have. (This is also called their atomic number).

C. Diagramming Atoms:

Using the position of an element in the Periodic Table (its atomic number) we can now draw a simple diagram of an atom of this element.

Example: From the Periodic Table in the front of the manual we see that Calcium has an atomic number of 20. This means 20 protons per Ca atom. Since uncombined atoms of elements are electrically balanced, this must mean this atom also has 20 electrons. We can draw the Ca atom now:

Ca Atom (atomic number 20):



Ca Atom

(The chemistry of an element's atom is not affected by its number of neutrons. So, for our purposes, the number of neutrons doesn't matter. We will just leave a question mark for the number of neutrons then.)

Application 2.
Draw simple diagrams like that above for each of the following atoms:
(a) Mg (b) C (c) Fe (d) H (e) Al (f) O (g) Si (h) K (i) Na

D. Patterns of Electrons

If electrons are outside the nucleus, the question arises, just what are they doing out there? Are they sitting still? Are they buzzing around the nucleus like bees around a flower. Or are they circling around the nucleus in a set pattern? This is not an easy question to answer, and all of the above suggestions have been considered. We will find it helpful to assume that electrons in atoms are orbiting around their nuclei like planets orbit around the sun in our solar system. (This idea was suggested by Niels Bohr in the early 1900's.) However, more than 1 electron can be in the same orbit. With this idea in mind, we can make a more detailed drawing of atoms of elements. For example look at the following diagrams:

Hydrogen (H) atom

Helium (He) atom

Oxygen (O) atom

Notice that in the oxygen atom, only 2 electrons are in the first (inner) orbit, but there are 6 in the second orbit. Rules have been developed describing the number of electrons allowed per orbit (an orbit is often called a shell).

Table 3:

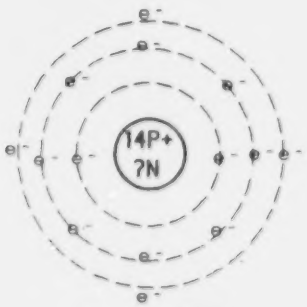
Electrons Allowed per Orbit Atoms

Orbit Number	*Maximum number of electrons allowed
1	2
2	8
* 3	8 or 18
* 4	2, 8, 18, or 32
* 5	2, 8, 18, or 32
* 6	2, 8, 18
* 7	2

(*The maximum number depends on the order of filling orbits, as described below).

Let us now look at this electron arrangement scheme for the atoms of elements, starting with the smaller atoms (look at the top left of the Periodic Table). As we would expect, hydrogen (H) has 1 electron in its first orbit, and helium (He) 2. Lithium (Li) has only 2 electrons in its first orbit since the first orbit is filled with 2 (see Table above) so 1 electron goes in its second orbit. Likewise from Be to Ne, electrons add to the second orbit until it is filled with 8 (see above table). In row 3 of the Periodic Table the same thing happens (from Na to Ar.) For example, a diagram for a silicon (Si) atom would be:

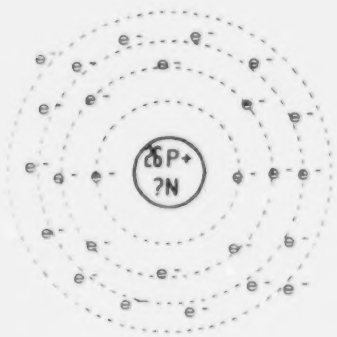
Silicon (Si) Atom



At elements number 19 and 20, however, the next electrons go in the 4th orbit not in the 3rd. But after that, electrons go back into the 3rd orbit (keeping 2 in the 4th orbit) until the 3rd orbit is filled with 18 at element Zn. After that the 4th orbit gains 6 more electrons to reach 8 at Kr.

For example, a diagram of the iron (Fe) atom would be:

Iron (Fe) Atom



Application 3.
Draw diagrams like the Fe atom for:
(a) Ca (b) P (c) Cu (d) C (e) Br

The top half of the Periodic Table contains almost all of the elements important in cement manufacture. Thus, we will not concern ourselves with detailed electronic diagrams of atoms below the 4th row in the Periodic Table.

E. Drawing Conclusions

Notice in the above Table how often the numbers 2 and 8 appear. This would lead us to conclude that there is something especially stable about a group of 2 or 8 electrons in an atom. Notice the last column in the Periodic Table (He, Ne, Ar, etc). These elements are all gases that rarely if ever react (combine) with other elements. For this reason, they are called the inert (or noble) gases. All of the atoms of these inert gases have 8 electrons in their outer orbit (except for Helium with 2). Can you explain why

the elements of this group are so unreactive chemically?

Perhaps you can begin to see, now, why a knowledge of the make-up of atoms can help us to explain the chemical behavior of the elements. In this section using atomic theory, we have already explained why the elements differ from each other (look back if you're not sure about this). Also, we have suggested why elements of the inert gas group have very little chemical reactivity (review this if necessary). As we continue, these atomic theories we are learning will help us better understand cement as well as materials and changes going on at home and in nature.

Section V Objectives

1. Be able to tell how ionic bonding occurs.

2. Be able to tell how covalent bonding occurs.

3. Be able to write formulas for ionic compounds, given a table of ions and their charges.

4. Be able to write dot diagrams for simple covalently bonded compounds.

5. Be able to tell what a polyatomic ion is.

V. Bonding Between Atoms, Chemical Formulas

A. Introduction

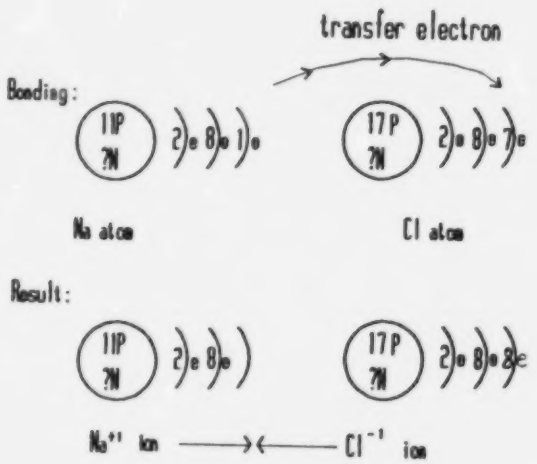
What holds atoms together in molecules like H_2O, CO_2, O_2, and NH_3? What holds crystals together in NaCl (salt) $CaCO_3$ (limestone), and $CaSO_4$ (anhydrite)? We can build simple models of these by putting sticks in styrofoam balls and hooking the balls together. Indeed, models like this can be very useful in accounting for many properties of substances. But what do the balls and sticks really stand for in terms of electrons and protons?

Chemists believe there are 2 kinds of bonds between atoms: ionic and covalent.

B. Ionic Bonding

Ionic bonding usually takes place when an atom with a few outer electrons (3 or less) combines with an atom with many outer electrons (5 to 7). (Remember any <u>outer</u> orbit has a maximum of 8 electrons except for row 1 elements with 2.) In other words, an element towards the left of the Periodic Table (metal) usually bonds ionically with an element toward the right (nonmetal). During the bonding process (chemical change), the atom with few outer electrons empties its outer shell and gives them to the atom with many outer electrons. This atom is then able to fill its outer shell with 8 electrons.

Example: sodium reacts with chlorine



When the sodium atom loses an electron, it has 1 more proton than electrons so it gets a positive charge (protons are +).

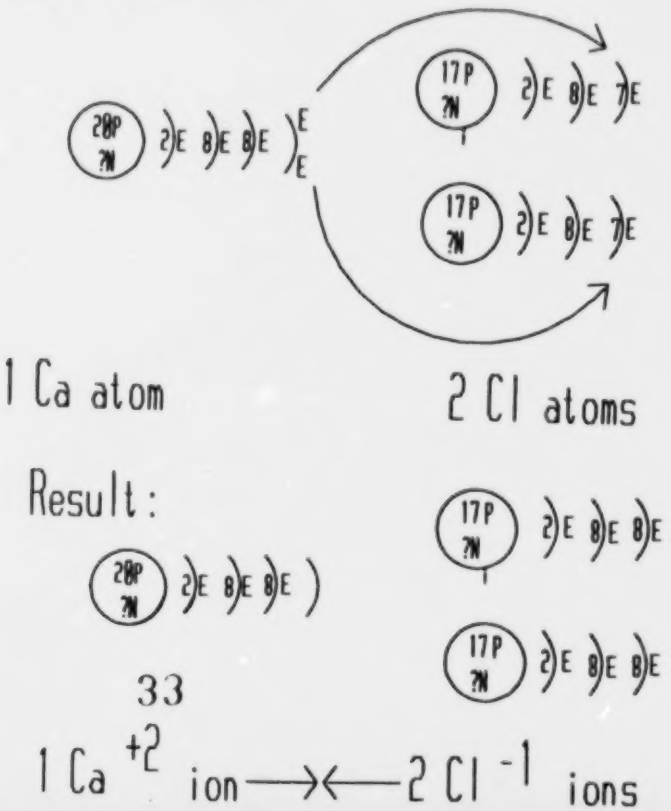
Application 1.
Why does the chlorine atom become negative?

The attraction between the positive Na^{+1} ion and negative Cl^{-1} is what is called the ionic bond. It is a very strong electrical attraction, much like between your hair and a comb on a cold dry day, except very much stronger. These ions then clump together in a crystalline regular pattern with alternating Na^{+1} and Cl^{-1} ions throughout the crystal.

Application 2.
Draw before and after diagrams of:
(1) Li combining with F
(2) Ca combining with O
(3) How does the rule: "8 outer electrons is a stable group" apply here?

What happens when elements are combining where 1 atom needs to give up 2 electrons to empty and the other needs to gain only 1 to fill its outer shell? The proportions of atoms then adjust themselves to satisfy both elements:

Example: Ca + Cl



We can write a formula for the result: $CaCl_2$

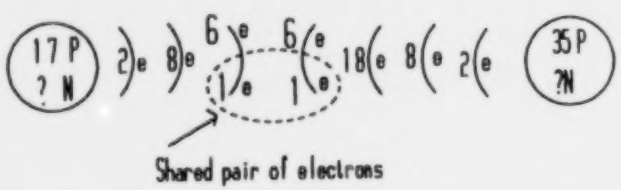
Application 3.
Draw before and after diagrams and write formulas for the following:

1. *Mg and F*
2. *Na and O*
3. *K and P*
4. *Al and Br*
5. *Al and O*

Application 4.
Can you see why most ionic compounds have set proportions (see section I) of their elements? What would happen if you mixed incorrect proportions and reacted them?

C. Covalent Bonding

Covalent bonding usually takes place when 2 nonmetallic elements combine, or a nonmetallic element combines with itself. This means that the combining elements have 4 or more outer electrons in their atoms. During the bonding process, electrons pair up. These electron pairs are then shared between the atoms being bonded to satisfy both of their outer shells. Example:

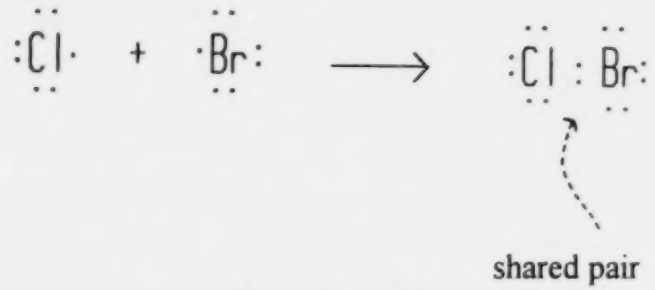


Cl atom Br atom

Notice that both of these elements outer orbits can now count the 2 electrons in the shared pair, giving 8 electrons for both. The positive protons in both nuclei are attracted toward the shared electron pair, producing the covalent bond.

Often a so-called dot diagram is drawn of just the outer shell electrons as follows:

or



Formula: ClBr

Note: The outer number of electrons (dots) of an element is usually the same as its group number in the Periodic Table.

Application 5.

Draw dot diagrams for the following, and write their formulas:

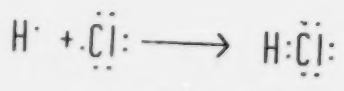
(1) Cl and Cl

(2) S and F (Hint: need more than 1 of which element?)

(3) O and Cl (Hint: need more than 1 of which element?)

Hydrogen usually bonds covalently in its compounds, because with 1 outer electron in its atom, its outer shell is already half filled (maximum of 2 electrons in 1st shell).

Example:



Formula HCl

Application 6.

Draw dot diagrams for the following and write their formulas:

1. H + O

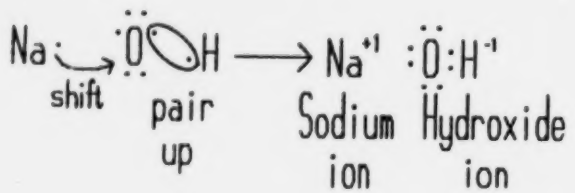
2. H + F

3. H + N

4. *H* + *C*
5. *H* + *H*

D. Combination Bonding

Many compounds show both ionic and covalent bonding. An example may make this clear:



Notice that within the hydroxide ion, the O and H bond covalently (shared electron pair). But the sodium ion has given its outer electron to the oxygen, producing an ionic bond between the positive sodium ion and the negative hydroxide ion. (This well known compound, NaOH is called sodium hydroxide, lye, or caustic soda, and is damaging to skin and eyes if not handled safely.)

There are many compounds of this type in nature and in the cement plant

Example:

Ca^{+2} CO_3^{-2}

ionic bonding covalent bonding

limestone

Ca^{+2} SO_4^{-2}

ionic bonding covalent bonding

calcined gypsum

Such compounds are usually said to be ionically bonded, but contain a polyatomic (many atoms) ion which is covalently bonded internally. The polyatomic ions above are CO_3^{-2} and SO_4^{-2}. We will not attempt to diagram these.

A list of commonly occurring ions (including some polyatomic ions) is given in Table 4. Remember, ions cannot exist by themselves, but only in combinations with ions of opposite charges.

Table 4:

Names, Formulas, and Charges of Some Common Ions

Positive Ions Negative Ions

Aluminum	Al^{+3}	Bromide	Br^{-1}
Calcium	Ca^{+2}	Chloride	Cl^{-1}
Hydrogen	H^{+}	Oxide	O^{-2}
Iron(II),ferrous	Fe^{+2}	Sulfide	S^{-2}
Iron(II), ferric	Fe^{+3}		
Magnesium	Mg^{+2}	*Carbonate	CO_3^{-2}
Potassium	K^{+1}	*Hydroxide	OH^{-1}
Sodium	Na^{+1}	*Nitrate	NO_3^{-1}
		*Phosphate	PO_4^{-3}
*{Ammonium	NH_4^{+1}	*Sulfate	SO_4^{-2}

*Polyatomic ions

E. Predicting Ionically Bonded Formulas

It seems reasonable that any positive ion in Table 1 should combine with any negative ion in that table to form a stable compound (Why?). This is usually true. Let's predict some of these compounds and their formulas. Calcium (Ca^{+2}) should

combine with Bromide (Br^{-1}). But their charges don't balance. We can fix this by taking 2 Br^{-1} ions for every Ca^{+2} ion:

$Ca^{+2}Br_2^{-1}$ name: Calcium bromide

Lets try another. Ammonium should combine with sulfide. Since ammonium is a polyatomic ion, place it in parenthesis with the charge outside: $(NH_4)^{+1}$. Now, take 2 (NH_4) ions for each S^{-2} Name: Ammonium sulfide $(NH_4)_2^{+1}S^{-2}$

Application 7.

Predict the formulas and names of:

1. *Sodium with each of the negative ions in Table 3.*
2. *Oxide with each of the positive ions in Table 3.*

Note: One way to balance charge in ionic formulas is to criss-cross the charges and make them subscripts, and then reduce subscripts to lowest terms:

Mg^{+2} O^{-2} becomes $Mg_2^{+2}O_2^{-2}$, which reduces to $Mg^{+2}O^{-2}$

Al^{+3} $(CO_3)^{-2}$ becomes $Al_2^{+3}(CO_3)_3^{-2}$ (and doesn't reduce).

Section VI Objectives

1. Be able to describe the following, in terms of molecular motion, effects of temperature on motion, and attraction between molecules:
    a. Why gases liquify and then solidify.
    b. Why solids melt and then evaporate.
    c. Why gases compress easily, but not solids and liquids.

2. Be able to explain why ionically bonded compounds usually melt higher than covalently bonded compounds.

3. Be able to explain why some covalently bonded molecules like diamond and quartz have very high melting points.

4. Be able to explain briefly the chemical make-up of many rocks, minerals, and clays.

5. Be able to describe how solutions behave compared to suspensions and tell why.

6. Describe the difference between crystalline and non-crystalline materials.

VI. Solids, Liquids, and Gases

A. Introduction

It is now time to look at another classification scheme for matter: solids, liquids, and gases.

Solids:	keep their shape and volume
Liquids:	keep their volume but not their shape. (Take the shape of their container)
Gases:	don't keep their shape or volume. (Completely and evenly fill their container)

Note: A fourth state of matter is called plasma. Since it exists primarily in stars and in fluorescent lights and neon lights, we will not need to examine it.

As with any classification scheme, there is some overlap. For example, silly putty will bounce, but will settle into a puddle-like blob if left on a table long enough. It could be called a solid-liquid.

Application 1.
Try to think of other materials that don't exactly fit the above scheme.

B. Explaining Solids, Liquids, and Gases.

Scientists now know that all solids can be liquified, and all liquids evaporated to a gas if heated hot enough. Likewise all gases can be liquified and then solidified if cooled low enough. The question is, what makes some materials gases, others liquids, and others solids at room temperature? Three ideas are necessary to explain this:

1. All atoms, ions, and molecules are in constant, rapid (speed of sound) motion.
2. Increasing the temperature speeds up the motion.
3. All molecules attract each other to some degree, but not as strongly as ionic and covalent bond attractions.

Application 2.
Try compressing a solid, a liquid, and a gas in syringe, and note the results.

Application 3.
Examine the molecular motion device to answer the following:

1. *How does the average speed of large molecules compare to small ones?*
2. *Why do gases fill up their container?*
3. *How close together are liquid molecules? (Why?)*
4. *What are 2 differences between liquid and solid molecules and their motions and arrangements?*
5. *Why do gases liquify?*
6. *Why do liquids solidify?*
7. *Why do solids melt?*
8. *Why do liquids evaporate (vaporize)?*
9. *Why are liquids and solids very hard to compress, but gases are easy?*

C. Bonding Types and Solids, Liquids, and Gases

1. Ionic Bonding

Most ionically bonded compounds are solids at room temperature, and have high melting points. (Most ionic compounds melt above 400°C.) This is true because these compounds consist of an alternating pattern of positive and negative ions in regular rows and layers, and all of the forces involved are strong ionic bonds. (Materials with regular internal patterns are said to be crystalline.)

Examples: NaCl (salt), CaO (quick lime), $Ca(OH)_2$ (slaked or hydrated lime), $CaCO_3$ (limestone), $CaSO_4$ (calcined gypsum).

2. Covalent Bonding - small molecules.

Most covalently bonded compounds consist of a few atoms bonded together to make small, molecular units. Compounds of this type are gases, liquids, or low melting solids (melting under 400°C). Examples includes water (H_2O), carbon dioxide (CO_2), glycol ($C_2H_4(OH)_2$), alcohol (C_2H_5OH), ammonia (NH_3), natural gas (CH_4), and naphthalene or mothballs ($C_{10}H_8$).

Inside these molecules are strong covalent bonds, but between the molecules are weaker, inter-molecular forces. Even at lower temperatures, the molecules are moving fast enough to change neighbors (roll over each other) to liquify. Somewhat higher temperatures cause their molecules to move fast enough to completely separate from each other and become gaseous. (The strong covalent bonds inside the molecules are not affected during these changes.)

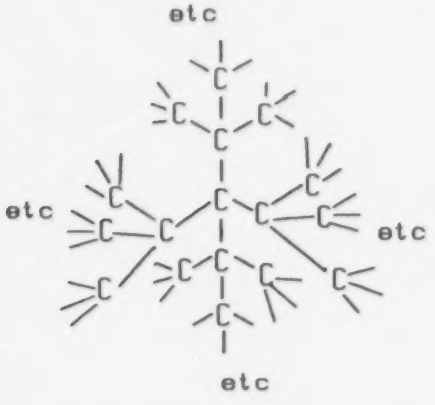
Depending on the relative strength of their inter-molecular forces, a substance will be a gas, liquid, or low melting solid at room temperature.

Application 4.
Tell which of these has stronger, medium, or weaker inter-molecular forces:

1. *Solid at room temperature.*
2. *Liquid at room temperature.*
3. *Gas at room temperature.*

3. Covalent Bonding - very large molecules

Some elements form strong enough covalent bonds between their own atoms to allow chains or networks of atoms to build up. This produces very large molecules containing thousands of atoms. A good example of this is carbon. Carbon atoms each need to bond 4 times (Can you explain why?). So a network of carbons can form into a giant molecule:

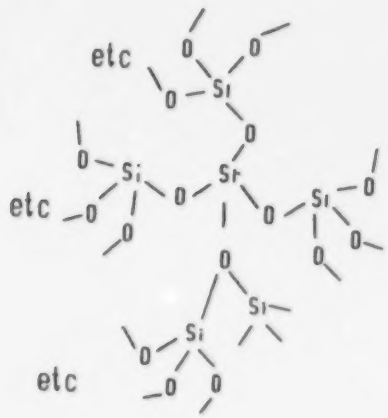


Note: This network of covalently bonded atoms extends in every direction for thousands of atoms.

This form of carbon is diamond. Diamond is a very high melting solid (greater than 3500°C).

Application 5.
Explain why diamond is so high melting.

Some combinations of elements form giant, network-like molecules like carbon. A good example is quartz or silicon dioxide (SiO_2). Instead of being a simple 3 atom molecule, though, silicon dioxide is a network of alternating, silicon and oxygen atoms covalently linked to each other (Si bonds 4 times, oxygen 2 times) etc.



Quartz (SiO_2) has a high melting point of over 1600°C. Quartz (like diamond) cannot liquify until strong, covalent bonds are broken.

4. Combination of ionic bonding and giant, covalently bonded polyatomic ions.

Silicon and oxygen can link together in network with extra electrons to form giant, polyatomic negative ions. These electrons are supplied by positive ions like Ca^{+2}, K^{+1}, Mg^{+2}, Fe^{+2}, or Na^{+1}. These positive ions are positioned throughout this polyatomic network in sufficient amounts to balance the negative charges.

Examples: About three-fourths of the earth's crust is made up of rocks, minerals, and clays containing silicon and oxygen linked in large networks as discussed above. Aluminum is tied into these networks in the clays.

D. Solutions and Suspensions

If a finely powdered solid such as clay, flour, or powdered sugar is mixed with a liquid like water, one of two results can occur. For example, clay stirred with water gives a cloudy liquid. If this mixture is allowed to sit quietly for a while, some or most of the clay will settle to the bottom. On the other hand, if powdered sugar is mixed with water, a clear liquid results. The sugar doesn't settle to the bottom on standing. Clay mixed with water gives a suspension. Sugar mixed with water gives a solution.

Application 6.
Try to explain the above observations of clay and sugar with water before reading on.

Water molecules pulling on the sugar molecules (and the constant motion of all molecules) cause the sugar molecule to separate from each other and wander around in the water. (Remember, all molecules attract other molecules). Sugar is said to dissolve in the water. Sugar is called the solute, and water the solvent.

Application 7.
Would sugar still dissolve even if were not finely ground? Why?

Clay molecules and ions can't be separated from each other by water molecules pulling on them, however.

So the tiny clay particles aren't changed much, but are just dispersed in the water.

Application 8.
1. *Would coarse clay particles form a suspension in water?*
2. *Why does clay settle out of water, but sugar doesn't?*
3. *How does flour act in water, and why?*
4. *The slurry being fed into the kiln acts like which: solution or suspension? (Give reasons).*
5. *Shake oil with water. Results?*

Solid solutes will usually dissolve in solvents only up to a certain amount. This amount is called its solubility. At that point, the solution is said to be saturated.

Any extra solid will settle to the bottom.

E. Crystalline and Non-Crystalline Solids

Solids (except for living matter) are formed in various ways, but most often one of these two ways:

(1). When liquids freeze (solidify).
(2). When saturated solutions cool or are evaporated.

As these solids form, the forces between atoms, ions and/or molecules usually cause these small particles to arrange themselves in orderly, repeating patterns. Such solids are said to be crystalline. Examples are salt, sugar and most minerals and metals. However, if the solids are formed too fast, these particles may not have time to arrange themselves. Instead they form a jumbled, disorderly pattern. Solids like this are called non-crystalline, glasses, or amorphous. (Also, the larger the molecules or ions, the harder it is for them to arrange themselves in the solid in an orderly pattern.) Examples include glass and clinker that has been rapidly cooled.

Most solids don't look crystalline on the outside. If examined internally with special X-ray machines, though, regular patterns can be shown. Also, crystal grains can often be seen with a microscope on specially prepared solid surfaces.

Application 9.
Examine the splotchy surface of galvanized sheet metal. (This material is made by dipping iron sheet metal in molten (liquid) zinc, which produces a zinc coating on the iron.) Explain what the splotches (grains) are.

Application 10.
Examine closely various rocks and minerals, and see if they give any evidence of being crystalline.

Application 11.
Does water ever give evidence of having a crystalline solid? Explain.

Section VII Objectives

1. Be able to list the ingredients for the Portland Cement made at Holnam.
2. Be able to explain why the Holnam plant is located here.
3. Be able to explain briefly why the limestone and clay are found here.
4. Be able to tell several changes that occur during calcining.
5. Be able to give a more complete formula for C_3S, C_2S, C_3A and C_4AF.
6. Be able to tell why gypsum is added to the cement.

VII. Chemistry of Portland Cement Manufacture

A. Introduction

Review section III on the History of Cement, and read the Holnam publication: "Helping Build Our Future".

B. Raw Materials

Raw materials used at the Holnam Plant include limestone, clay, iron oxide, sand, fly ash, and mill scale. Fuels to heat the kiln include coal, fuel oil, natural gas, and used industrial solvents.

1. Limestone is chiefly $CaCO_3$. When $CaCO_3$ is heated in the kiln above 800°C, it begins to decompose and lose carbon dioxide gas, leaving calcium oxide:

$$CaCO_3 \xrightarrow[\text{decarbonation}]{> 800°C} CaO + CO_2$$

The CaO is known as lime or quick lime, and is the chief ingredient in cement manufacture (more than 60%).

2. Clays are mostly mixtures of aluminum, iron, silicon, and oxygen compounds, with some combined water. They are called hydrous aluminum silicates (hydrous refers to combined water; the - ate ending shows oxygen). As clays are calcined above 600°C, they lose their combined water and form dehydrated aluminum silicates. They can be shown in simplified form as a combination of aluminum oxide, iron oxide, and silicon dioxide: $Al_2O_3 \bullet Fe_2O_3 \bullet SiO_2$

SiO_2 is usually present in cement around 20%, and Al_2O_3 around 5%, and Fe_2O_3 around 2%.

3. Iron oxide from the Georgetown Steel Mill is mostly Fe_2O_3. About 2 to 5% of Fe_2O_3 is present in the cement manufactured here.

4. Sand is a source of SiO_2, although it may have other minerals in it. Small amounts of sand may be added to the kiln feed to adjust the silica content.

5. Fly ash (ash from burning coal) and mill scale (from manufacturing iron and steel) are other sources of iron oxide, and aluminum silicates.

Table 5:

Summary of Components of Portland Cements

	Percent
CaO	60 - 67%
SiO_2	17 - 25%
Al_2O_3	3 - 8%
Fe_2O_3	0.5-6.0%
Other (MgO, Na_2O, K_2O) small amounts	

6. The fuels to heat the kiln will be discussed in a later section.

C. Site Selection

The need for cement in the Southeast and the availability of raw materials are the two main reasons for locating Holnam's Holly Hill Cement Plant here. How do the limestone and clay happen to be here? Geologists give us good answers to these questions.

A small percentage of ocean water (which is still a very large amount) is calcium carbonate. This calcium carbonate is thought to end up in limestone in one of two ways. The most direct way is when isolated parts of the ocean evaporate or dry up, depositing the calcium carbonate on the ocean floor like mud. These layers of mostly $CaCO_3$ compact and harden into limestone.

Another way limestone is produced is from the organisms in the ocean. Many ocean creatures (like oysters, clams, snails, and corals) draw calcium carbonate from the water to make shells and skeletons. Most of these shells and skeletons settle and are broken up when the animals die, and form sands or mud. These layers of mostly calcium carbonate then compact to make limestone. The deeper these layers are buried, the harder and sturdier the limestone becomes.

Application 1.

(a) Which way do you think Holnam's limestone was formed? Why? How long

ago was this? Explain.

(b) What happened to the ocean which once covered Holnam's limestone(The ocean extended up to Columbia.)?

(c) Was the Holnam limestone ever buried very deep or not? Explain.

The layer of clay which covers the limestone in the quarry comes from a different source, geologists say. Clays are formed when rocks like granite (found above Columbia) that have aluminum silicate minerals are weathered. Weathering causes these rocks to crumble into fine particles. Clay formed this way may stay near the rocks that produced them (residual clays). However, these clays may be carried by wind or water to other places and deposited. Such deposits are called sedimentary.

Application 2.

(a) Do you think the clay covering the limestone in the quarry is residual or sedimentary? Why?

D. Preparation and Handling of Raw Materials

After quarrying the limestone, it is crushed to smaller size. Then the proper proportions of limestone, clay, iron oxide, mill scale, fly ash, and sand are blended and ground with water to form a slurry. Chemical analysis of the components is done at every stage to insure the right proportions.

E. Calcining

The following changes take place in the rotating kiln as the ingredients pass through:

(1) Evaporation of liquid water from the slurry (> 100°C)

(2) Removal of combined water from the clay (> 600°C)

(3) Removal of CO_2 from the limestone, leaving CaO (> 800°C)

(4) Partial melting of the materials (>1400°C)

(5) Chemical reactions between the various oxides (CaO, SiO_2, Al_2O_3, and Fe_2O_3). Chemical bonds are broken and reformed to produce complex calcium, aluminum, silicon, iron, and oxygen compounds at temperatures above 1400°C (2600°F). The 4 main compounds that form in Portland Cement during heating are:

Table 6:

Name	Simplified Formula	Abbreviation
tricalcium silicate	$3CaO \bullet SiO_2$	C_3S
dicalcium silicate	$2CaO \bullet SiO_2$	C_2S
tricalcium aluminate	$3CaO \bullet Al_2O_3$	C_3A
*brownmillerite	$4CaO \bullet Al_2O_3 \bullet Fe_2O_3$	C_4AF

*** Probably a mixture of 2 compounds.**

The simplified formulas above don't show the bonding patterns in these compounds. (Look at Section VI, C_4, for an indication of some bonding possibilities.)

The first two compounds above (C_3S and C_2S) provide most of the cementing capability on setting of the cement. The last 2 (C_3A and C_4AF) adjust setting time and aid in the gaining of water by C_3S and C_2S on setting. Some uncombined CaO (free lime) remains in the cement after calcining.

***Note to Teacher**

(Visual Explanation of Reactions in Kiln By Demonstration by teacher)
***(Indothermic Reactions** - absorb Heat and must have Heat to happen, such as boiling water. **Exothermic Reactions** - give off Heat when they react, such as fire. All reactions in the kiln up to the formation of the C_3S are indothermic. The C_3S reaction is exothermic which allows you to see it take place in a clear kiln).*

Application 3.

(a) Why do high temperatures in the kiln cause strong bonds to break and reform more easily?
(b) Why does partial melting during calcining speed reactions to make cement compounds? (Compare solids and liquids.)
(c) Which would react faster, finely ground or coarsely ground ingredients? Explain. (Compare rate of digestion of completely chewed versus partly chewed food.)

F. Cooling the Clinker from the Kiln

As the hot clinker from the kiln is cooled, most of the material in the clinker crystallizes into the compounds C_3S, C_2S, C_3A, and C_4AF. However, a small amount of the material in the clinker remains in the glassy (non-crystalline or amorphous) state.

Application 4.
If the clinker were cooled faster, would a greater or less proportion of glass form in the clinker?

An important part of efficient plant operation is recovering and recycling the heat from the cooling of the clinker.

Application 5.
What use is made of the heat gotten from the cooling clinker? How?

G. Grinding and Compounding the Final Product

The clinker is stored in the Dome until it is needed. Then it is mixed with a small amount of gypsum ($CaSO_4 \bullet 2H_20$) and ground in the finish mill to the desired degree of fineness. The gypsum helps control the rate of setting of the cement when the cement is being used. After grinding, the cement is ready to be shipped to the user in bags or in bulk.

H. Five Types of Portland Cement

The American Society for Testing Materials (ASTM) recognizes the following five types of Portland Cements:

Table 7:

Type I	**General Use Cement**
Type II	**Moderate Heat of Hardening Cement**

Type III	**High Early-Strength Cement**
Type IV	**Low-Heat Cement**
Type V	**Sulfate-Resisting Cement**

Most of the cement produced here at Holnam, Holly Hill are Types I/II cement. I/II meets Type I physical strengths and Type II chemical analysis.

Application 6.
Examine samples of the types of cement produced by Holnam.

I. Setting of Portland Cement

Portland Cement is rarely used by itself, but is mixed with various amounts of sand and gravel when used. Sand, gravel, and other similar additives are called aggregate. The combination of Portland Cement, sand, other aggregate, and water produces concrete.

The setting of cement in concrete is a complex process involving both physical and chemical changes in stages. Some of these involve partial solution , separation from solution, gelling, and hydration (reaction of C_3S, C_2S, C_3A, and C_4AF with water to chemically bond the water into these compounds). An important final result is the formation of crystals of hydrated calcium silicate, which give the strength to the set cement. Since most of these reactions are exothermic (produce heat), care must be taken to adjust setting rates to prevent overheating.

Application 7.
Mix a small amount of sand and cement with water in a plastic cup and observe it over a period of time. Note setting time, hardness, etc.

Application 8.
Repeat previous application, but push a pencil into the hardening mass to leave a hole large enough for a thermometer. Measure the temperature of the hardening mass and compare to the room temperature. Results?

Section VIII Objectives

1. Be able to explain how the central control room directs plant operations.
2. Be able to tell what chemical analysis is.
3. Be able to list 5 of the key elements used in making cement.
4. Be able to compare wet methods of analysis to instrumental methods.
5. Be able to explain briefly how the X-ray Fluorescence Spectrograph works.
6. Be able to describe several tests that are run in the laboratory on the finished cement product.

VIII. Control, Analysis, and Testing

A. Process Control

Modern manufacturing plants are more and more automated. This allows a majority of the plant processes to be controlled and managed at central locations. Holnam's processes are highly automated, allowing most of the processes to be managed at the central control room.

In order to do this, many sensors (detection elements) must feed temperatures, pressures, flow rates, and weights to the control room. The laboratory provides chemical analyses. The control room personnel, aided by instruments and computers, are aware of what's happening throughout the plant. They send signals out to remote-controlled switches and values, thus regulating the cement manufacturing process.

Application 1.
Visit the control room and see how much of the manufacturing process is controlled there.

B. Analysis

1. Introduction

Chemical analysis means finding out what elements or compounds make-up a material and measuring how much of them are present in that material. In order to produce a quality cement, it is crucial to analyze the components at every stage of cement manufacture.

As might be expected, the key elements whose proportions need to be followed and adjusted are Ca, Si, Al, O, and Fe. Certain compounds need to be tested for, including free lime (CaO), and gypsum ($CaSO_4 \bullet 2H_2O$). In the finished product, the proportions of Ca_3S, Ca_2S, Ca_3A, and Ca_4AF must be calculated for. Other minor ingredients like Na, K, P, and Ti are also analyzed for.

The older, so-called wet methods of analysis were reasonably accurate, but very slow. These methods involved dissolving, reacting, precipitating, filtering, firing,

weighing, etc. Complete analyses of the components in cement took hours, making it difficult to use the results to control a fast-moving manufacturing process.

Modern methods of analysis use special, usually expensive instruments, to analyze for components. These instrumental methods of analysis can often give results in less than a minute, instead of in hours!

Application 2.
If available, look at the results of a blood analysis done in a medical lab, and compare it to the results of one of Holnam's analyses. Are there any similar elements tested for?

2. The X-ray Fluorescence Spectrograph

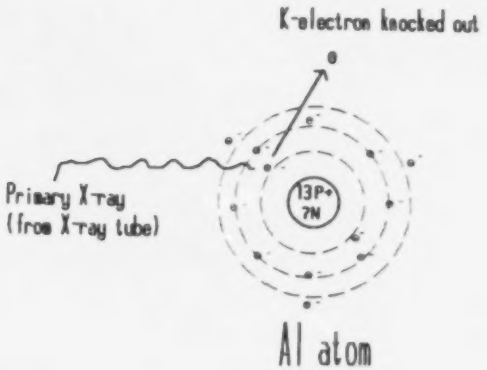
All of the chemical analyses at Holnam are done in the laboratory. The "work-horse" at the laboratory is the instrument called the X-ray Fluorescence Spectrograph (abbreviate XFS). It is a very expensive and complicated instrument, but the way it works is not too hard to explain. The steps involved are:
(a) Prepare a cement sample by compacting into a wafer.
(b) Insert wafer sample in XFS
(c) Bombard the sample with X-rays (called primary X-rays)
(d) Measure the intensity and frequency (energy) of the secondary X-rays given off by the sample
(e) Calculate and print out results

We can better understand how this machine works by getting some background on X-rays. X-rays belong to a whole class of rays called electromagnetic radiation. Other members in this class include radio, light rays, infra-red, ultra-violet, and gamma rays. They are all similar in speed (speed of light), but differ in energy, how they are produced, and how they are detected. For example, light is produced by a light bulb has rather low energy (frequency) and is detected by your eye or camera film. But X-rays are produced in an x-ray tube, possess high energy (frequency), and are detected by X-ray detectors (something like Geiger counters). X-rays can also be detected by film.

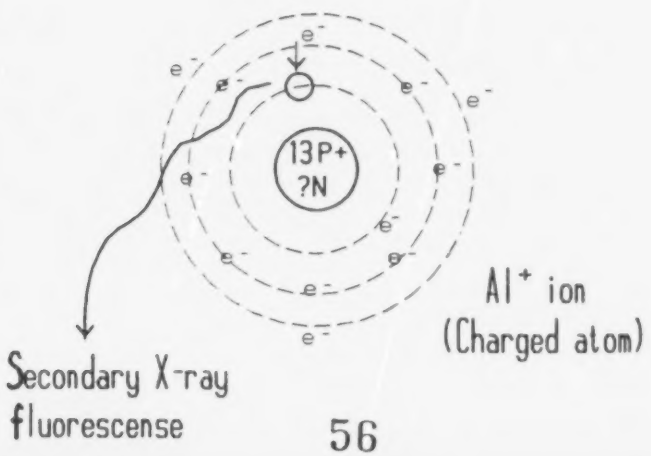
Application 2b.
Look through a prism at a light source and notice the spectrum of colors.

The key to understanding the XFS machine is to understand how the secondary X-rays from the sample are produced. They come from disturbing the innermost electrons of the sample atoms.

The innermost electrons (first shell or K-shell electrons) in atoms are difficult to disturb, and remain unaffected even by high temperatures (like in the kiln), and during chemical reactions. However, X-rays have sufficient energy (frequency) and penetrating power to interact with these inner electrons (as well as outer electrons) and knock them completely out of their atoms:



The result is an electron vacancy in the atom. In a fraction of a second, electrons jump in from outer shell to fill the vacancy and give off energy in the form of secondary X-rays. The giving off of radiation when a higher energy atom changes to a lower energy state after a delay is called fluorescence.



Application 3.
Some materials are activated by light rays, and then later glow in the dark (fluorescence) for a while. Compare these with the X-ray fluorescence we are discussing.

The reason X-ray fluorescence can be used to tell what elements are present in the sample is as follows. The energy (frequency) of the secondary X-rays given off by disturbing inner electrons in an atom depends on how many protons are in that atom. Since the X-ray detectors in the XFS machine can tell the energy (frequency) of the secondary X-rays, it can identify which elements are present.

Also, these detectors can tell how many rays of a given energy (frequency) are given off. This tells how many atoms of that element are present.

Thus, the XFS machine can tell what kind of atoms (elements) are in a sample and how many of them are present. This machine only analyzes for elements, though, and not compounds. From the element results, though, compound percentages can be calculated.

Application 4.
(a) Examine print-outs of cement analyses from the XFS.
(b) Take a tour of the XFS at the laboratory.

3. Free Lime Test

If too much lime (CaO) is present or is not combined properly in the final product, it can result in unsound concrete due to over-expansion on setting. The XFS machine cannot determine the amount of free lime present, so it must be done with a wet method.

The very finely ground cement sample is shaken and heated with the solvent ethylene glycol (also used for antifreeze). This dissolves the free lime in the ethylene glycol. The amount of dissolved CaO is then found by seeing how much hydrochloric acid it takes to react with it, using a dye to tell when the reaction is done. This is called a titration.

4. Other Analyses

Other analyses are done when special problems arise during the manufacture or use of cement. One analysis involves the use of a (polarizing) microscope. By polishing and etching clinker samples, the kind and size of the crystals in the clinker can be seen.

Application 5.
Visit the crystallography room of the lab and look at clinker samples through the microscope.

C. Testing

A variety of tests are run in the laboratory on the finished cement product and its setting properties. These include:

(1) Setting (hardening) times.
(2) Compression strengths after different times of setting.
(3) Length change during setting.
(4) Air content.

Compression strength tests are run on 2 inch cubes of cement mixed with sand and water and are then placed in a machine that can exert thousands of pounds of force inward on the cube. Yield strengths are measured.

Application 6.
Visit the testing area of the laboratory and see how the above tests are run.

Application 7.
Learn to run as many of the following tests as time allows:
X-ray, free lime, Blaine, SO_3, and physical tests.

Section IX Objectives

1. Be able to give the old and new definitions for organic compounds.
2. Be able to explain why C and Si are unique in terms of their bonding abilities.
3. Be able to name several hydrocarbons and draw their structural diagrams.
4. Be able to describe an organic alcohol.
5. Be able to name several classes of organic compounds.
6. Be able to tell 3 important sources of organic chemicals.
7. Be able to tell why most organic compounds can be used as fuels and why.
8. Be able to explain the advantages of using waste organics as a kiln fuel supplement.

IX. Organic Chemistry, Fuels

A. Introduction

It would seem that organic chemicals would be chemicals produced by living organisms (plants and animals). Up to the mid 1800's, this was considered to be the case. Then, more and more of these chemicals from living things were able to be synthesized (made) from non-living materials. Also, many related compounds never known in nature before were synthesized. For these reasons, organic compounds are now defined more broadly as carbon compounds.

Application 1.
(a) Explain how and why the compound classification system (organic and inorganic compounds) has changed over the years.
(b) Should $CaCO_3$ be called organic or inorganic? Why?

B. Uniqueness of the Elements Carbon and Silicon

Just as silicon-oxygen linkages form the backbone for most of the inorganic chemicals found in rocks, clays, sands, and minerals, so do carbon - carbon linkages form the backbone for organic compounds. Silicon and carbon are unique in their ability to form strong, covalently bonded chains and networks.

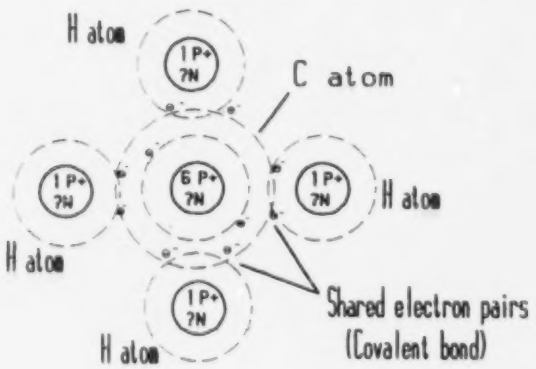
Application 2.
After looking at the Periodic Table, is it surprising carbon and silicon atoms are similar in chain-forming abilities? Explain.

C. Organic Compounds (C, H, O, N)

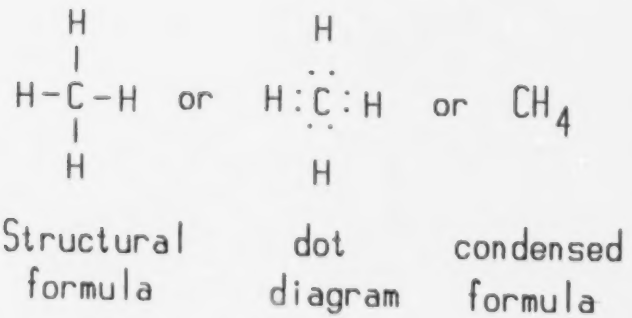
There are thousands of known organic compounds. All of these contain carbon, and almost all also contain hydrogen. Over half of the compounds contain oxygen, and many contain nitrogen. The elements C, H, O, and N in various bonding patterns make up almost all organic compounds.

D. Hydrocarbons

Compounds made up only of carbon and hydrogen are called hydrocarbons. The simplest hydrocarbon is called methane. Remember that carbon needs 4 covalent bonds to complete its outer electron shell with 8, but hydrogen only needs one covalent bond. Methane can be drawn:



This can be represented more simply as:



Methane is the compound that makes up most (over 90%) of natural gas. (It is also produced in the digestion of food in a cows stomach and when cow manure decomposes.) It is used as a fuel for heating homes, kilns, etc.

Since carbon can link to itself, another hydrocarbon is:

Ethane

The following is a list of some hydrocarbons:

Table 8:

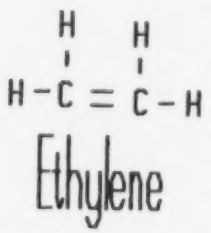
Name	Condensed Formula
Methane	**CH_4**
Ethane	**$CH_3 - CH_3$**
Propane	**$CH_3 - CH_2 - CH_3$**
Butane	**$CH_3 - CH_2 - CH_2 - CH_3$**
Pentane	**$CH_3 - CH_2 - CH_2 - CH_2 - CH_3$**
Hexane	**$CH_3 - (CH_2)_4 - CH_3$**
Heptane	**$CH_3 - (CH_2)_5 - CH_3$**
Octane	**$CH_3 - (CH_2)_6 - CH_3$**

Most of the above are found in oil wells and are used as fuels. You recognize propane and butane as the components of bottled gas. Pentanes and hexanes make up gasoline. Longer hydrocarbons make up kerosene, diesel fuels, and fuel oils.

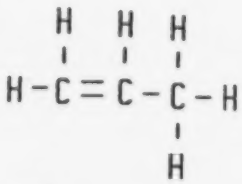
Application 3.
Draw structural diagrams and make styrofoam models of the above hydrocarbons.

E. Carbon - Carbon Double - Bonding

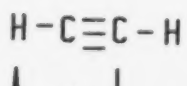
Not only can carbon bond to itself once, it can also double or triple bond to itself:



Ethylene



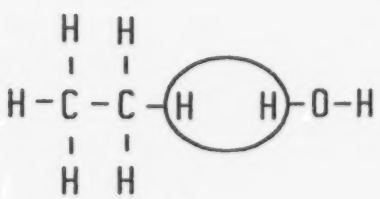
Propylene

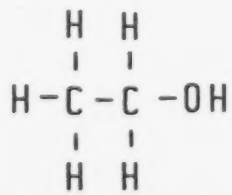


Acetylene

F. Alcohols

The simplest oxygen containing organic compounds are the alcohols. They can be thought of as a cross between water and a hydrocarbon (but they aren't made that way).





ethyl alcohol
(grain or beverage alcohol)

Other alcohols are:

Table 9:

Name	Formula
methyl alcohol	**CH_3 - OH**
ethyl alcohol	**CH_3 - CH_2 - OH**
propyl alcohol	**CH_3 - CH_2 - CH_2 - OH**
butyl alcohol	**CH_3 - CH_2 - CH_2 - CH_2 - OH**
ethylene glycol	**CH_2OH - CH_2OH**

Notice that the names all start like the hydrocarbons, but have a -yl on them instead of -ane. They all end in -ol. If we represent any hydrocarbon as R-H, we can represent any alcohol as R-OH. The -OH group of alcohols is called its characteristic or functional group. (R - stands for hydrocarbon radical).

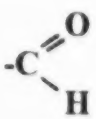
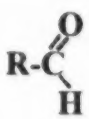
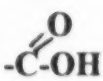
Application 4.

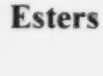
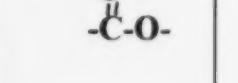
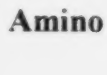
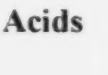
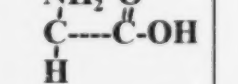
(a) Draw structional diagrams for the above alcohols and build styrofoam models.
(b) There are 2 propyl alcohols: normal propyl alcohol and isopropyl alcohol. Try to build and draw both of their molecules.

G. Classes of Organic Compounds

There are dozens of classes of organic compounds, which makes studying organic chemistry quite involved. A few of these classes are as follows:

Table 10:

Class	Functional Group	General Formula	Common Example
Hydrocarbons	**-H**	**R-H**	**propane, CH_3-CH_2-CH_3 (used in bottled gas)**
Alcohols	**-OH**	**R-OH**	**ethyl alcohol, CH_3-CH_2-OH (alcoholic beverages, industrial solvent)**
Aldehydes			**formaldehyde,** **(preservative)**
Ketones			**acetone,** **(nail polish remover, solvent)**
Organic Acids			**acetic acid,** **(vinegar is 5% acid and water)**

Ethers	**-O-**	**R-O-R'**	**diethyl ether, CH_3-CH_2-O-CH_2-CH_3 (used as an anesthetic)**
Esters			**ethyl acetate**  **(used as a paint solvent)**
Amines	**$-NH_2$**	**$R-NH_2$**	**ethyl amine, CH_3-CH_2-NH_2 (found in fish)**
Amino Acids			**alamine,**  **(a constituent of proteins)**

The most reactive part of these organic compounds is the functional group part, not the hydrocarbon (R-) part. Except during burning, the R- part usually remains unchanged.

Application 5.

Examine a chemistry handbook (CRC Handbook of Chemistry and Physics or Lange's Handbook of Chemistry) and find the section on organic compounds.

(a) About how many organic compounds are listed?

(b) Find some of the above compounds and see what information is given about them.

(c) Find the section on inorganic compounds. Are there more or less inorganic than organic compounds? Is this surprising?

H. Sources of Organic Compounds

There are three main sources of organic chemicals:

(1) Animal and plant products
(2) Petroleum (oil wells)
(3) Coal

Application 6.
Use an Encyclopedia and find out how coal and oil (petroleum) are formed.

Many of the compounds from these sources are separated and used unchanged. More and more, however, source compounds are reacted and changed to new compounds for greater varieties of uses. For example, hydrocarbons from petroleum are reacted to make plastics used in synthetic fabrics, rubber, auto parts, milk containers, fishing rods, etc.

I. Importance of Organic Chemistry

A knowledge of organic compounds and how they react is important in the following fields and industries:

(1) Pharmaceuticals
(2) Medicine and Health
(3) Nutrition
(4) Plastics and Synthetic fabrics
(5) Agriculture
(6) Forestry products
(7) Textile industry
(8) Fuels and Transportation

Application 7.
Tell how knowing organic chemistry would help in each of the above fields.

J. Fuels

Almost all organic compounds will burn if heated hot enough to ignite in the

presence of oxygen or air. This is not too surprising since all contain carbon and most contain hydrogen. The carbon part of the organic compound burns to make CO_2 and the hydrogen part burns to make H_2O. An example is:

$2CH_3$-CH_2-OH	**+**	**$7O_2$**	**----->**	**$4CO_2$**	**+**	**$6H_2O$**	**+**	**heat**
ethyl alcohol	**+**	**oxygen**	**----->**	**carbon dioxide**	**+**	**water**	**+**	**heat**

Most organic compounds can be sold for higher prices for other uses than as fuels. For this reason, less expensive organics like the hydrocarbons, coal, and wood are commonly used as fuels.

Application 8.
List the fuels used in the following:

(1) Electric generating plants
(2) Cars
(3) Trucks
(4) Trains
(5) Airplanes
(6) Home heating
(7) Industrial heating
(8) Boats and Ships

Many organic compounds used in business and industry must be disposed of in some way after they get too dirty with use. Examples include waste oil from automobiles and trucks, solvents to clean auto parts or other manufactured parts, and fluids used to cool drill, lathe and milling machine cutters. Most of these waste organic chemicals can be separated, cleaned, and recycled. When it costs more to recycle these materials than their resale value, through, then they must be disposed of. One way is to dispose of them in landfills. As the amounts of waste organics increase, the chance of soil and water pollution becomes greater.

Another alternative is to burn these waste organics. This raises the question of air pollution. However, if certain type waste organics are screened out, and high enough burning temperatures are used to completely burn the materials, this method is a satisfactory way for their disposal.

Safety Kleen is a company dealing in disposing of these waste organic solvents, coolants, etc. They provide Holnam with a source of fairly inexpensive liquid fuel (waste organics) to supplement the primary kiln fuel, coal. With proper controls, this provides Holnam, Safety Kleen, and society at large with advantages. Holnam gets an inexpensive heat source. Safety Kleen gets a way to economically dispose of their waste organics. And the public benefits by having these waste organics (which are an automatic result of our Technological Age) safely and cleanly disposed of with minimum pollution and cost.

Application 9.

(a) Why does the cement kiln provide an ideal burning environment for waste organics?

(b) What are the main products of burning organics? Do these pollute the air?

(c) Tour the Safety Kleen lab and find out how they monitor the waste organics.

(d) Why are organic compounds containing chlorine screened out?

(e) What other chemicals beside chlorine must be minimized?

(f) Explain how any metals in the waste organics being burned can end up in the cement being produced in basic compounds normally insoluable in nature.

QUESTIONS

Directions: Look at a, b and c and choose which of the three chemical basics is the appropriate answer for the left handed column of chemical basics. Put the letter of your answer in the blank.

I. CHEMICAL BASICS

____1.	Has only one kind of molecule but more than 1 kind of atom	a.	element
____2.	Has only 1 kind of atom	b.	compound
____3.	Its components retain most of their characteristics	c.	mixture
____4.	H_2O is an example		
____5.	Si is an example		
____6.	Salt is an example		
____7.	Air is an example		
____8.	CO_2 is an example		
____9.	O_2 is an example		
___10.	There are only 109 of these known		
___11.	Most natural occurring materials are which of these?		
12.	Elements can be divided into what 2 groups?		

_____ and _____.

Directions: Match the changes and properties on the right with their descriptions on the left. Put the letter of your answer in the blank.

___13.	Burning of gasoline	a.	Physical Change
___14.	Color of dye	b.	Chemical Change
___15.	Strength of cement	c.	Physical Property
___16.	Evaporation of alcohol	d.	Chemical Property
___17.	Melting of ice		
___18.	Ion's rusting ability		

Write your answers.

19. What is the Periodic Table?.

20. Tell what classification (grouping) schemes are used for in Chemistry.

21. Tell how Model Systems are used in Chemistry.

II. METRIC

Directions: Write your answer.

1. Tell the advantages and disadvantages of our changing to the metric system of measurement in this country.

Directions: Match the items on the right to the description on the left.

____2.	Used to measure length	a.	liter
____3.	Used to measure volume	b.	gram
____4.	Used to measure mass	c.	°Celsius
____5.	Used to measure temperature	d.	meter

Directions: Choose the correct answer and put the letter of the correct answer in the blanks on the left.

____6. A millimeter is

a. the same as a liter
b. 40 grams
c. one-thousandth of a meter
d. one-tenth of a meter
e. the same as a milliliter

____7. A kilogram is

a. about 2 pounds
b. about 2 ounces
c. almost a ton
d. used to measure volume

____8. Normal room temperature is about

a. 10°C
b. 25°C
c. 50°C
d. 75°C

____9. An eyedropper of liquid is about

a. 1 liter
b. 1 deciliter
c. 1 centiliter
d. 1 milliliter

___10. A yard is a little less than

a. a meter
b. a decimeter
c. a centimeter
d. a millimeter

III. History of Cement

Directions: Place T or F on the line next to the number of the question.

True or False

____1. The Romans were the first to use calcined gypsum as a cementing material.

____2. Calcining means mixing with lime.

____3. Portland Cement was given its name in the early 1800's.

____4. It has been found that coarsely ground cement works better than finely ground cement.

____5. It was found that a certain amount of clay must be added to the limestone to make a good cement.

____6. A hydraulic cement is one that will set up under water.

____7. Cement and concrete are essentially the same thing.

____8. The cement industry developed in the U.S. in the early 1800's because of the need for cement to build bridges.

____9. Portland Cement is fired at a high enough temperature to completely melt the mixture and produce clinker.

___10. Limestone is mostly calcium carbonate.

IV. Make - Up of Atoms of the Elements

1. Name the 3 kinds of particles that make the atom: _____, _____ and _____.

2. Describe how these 3 kinds of particles are arranged in the atom.

_____

_____

_____

_____

3. The nucleus of an atom has what kind of overall charge? _____.

4. Each atom is like every other atom of that element because it has the same number of what kind of particle in its nucleus? _____.

Using the Periodic Table, diagram the following atoms with the Bohr shell diagram:

5. Li

6. Si

7. H

8. Al

9. Fe

V. Bonding Between Atoms, Chemical Formulas

Directions: Match a or b with the correct description on the left. Put you answer in the blank.

___1. Bonding by sharing electron pairs between atoms — a. ionic bonding

___2. Bonding by transferring electrons one atom to another — b. covalent bonding

___3. Bonding when an atom with 3 or less outer electrons combines with an atom having 5 to 7 electrons

___4. Bonding when 2 atoms combine whose outer shells are half-filled or more

___5. Bonding when 2 nonmetals combine

___6. Bonding when a metal combines with a nonmetal

Balance charge (write correct formulas) for the following compounds:

7. Ca^{+2} with O^{-2}
8. Na^{+1} with S^{-2}
9. Al^{+3} with F^{-1}
10. Ca^{+2} with NO_3^{-1}
11. Fe^{+3} with O^{-2}

Draw dot diagrams (choose the right number of atoms) for the following:

12. S with Cl
13. H with C

14. Explain briefly in terms of outer electrons why the inert (noble) gas elements in the last column of the Periodic Table hardly react at all. Use back of paper if necessary.

VI. Solids, Liquids, and Gases

Match
Directions: Place your answer in the blank on the left.

___1. Keep their volumes, but not their shape.

___2. Don't keep their volume or shape

___3. Keep their volume and shape

___4. Their molecules are far apart

___5. Their molecules are close together, but not in orderly patterns

___6. Their molecules are close together, usually in orderly patterns

___7. They are easy to compress

a. solids

b. liquids

c. gases

Multiple Choices
Directions: Place the letter of the correct response to the left of the number.

___8. Gases change to liquids because their molecules
   a. slow down and stop
   b. attract each other
   c. react chemically with each other
   d. break up into smaller particles

___9. Substances with higher melting points have molecules that:
   a. are small
   b. are bonded covalently
   c. have higher attractions between molecules
   d. are easily split

__10. All molecules are:
a. round
b. large
c. always far apart
d. always moving

__11. Ionically bonded compounds usually are:
a. high melting
b. low boiling
c. low melting
d. liquids at room temperature

__12. An element that forms strong enough covalent bonds with itself to produce chains is:

a. Nitrogen
b. Oxygen
c. Hydrogen
d. Carbon

__13. The element which is the backbone of most rocks and minerals is:
a. nitrogen
b. carbon
c. silicon
d. iodine

__14. A suspension usually:
a. is clear
b. is cloudy
c. will not settle
d. is hard to separate into its components

__15. Most minerals are:
a. crystalline
b. disordered internally
c. glassy
d. amorphous

VII. Chemistry of Portland Cement

1. Name the raw materials used to make cement at Holnam.

_____

_____

_____

2. What fuels are used to heat the kiln?

_____

_____

_____

3. The compound, $CaCO_3$, is found in which raw material?

_____

4. Al, Si, and O are found combined in which raw material?_____

5. What happens to $CaCO_3$ when it is heated above 800°C?_____

_____

_____

6. Give 2 reasons why Holnam Cement Plant is located here_____,
and _____.

7. Where did the limestone in the quarry come from? _____

_____

_____

8. Where did the clay in the quarry come from? _____

_____

_____.

9. What does calcining mean? _____

_____.

10. Name 3 or 4 things that happen to the raw materials as they pass through the kiln: _____

_____

_____.

11. What is C_3S? _____.

12. Why is gypsum added to the finished cement? _____

_____

_____.

13. What is the main chemical process that occurs when cement sets up?

_____

_____.

VIII. Control, Analysis, and Testing

1. Why is chemical analysis important in cement manufacture? _____
_____
_____.

2. What is the name of CaO? _____.

True - False
Directions: Place T or F in the blank to the left of the statement.

__3. Wet methods of chemical analysis are usually slow.

__4. Most of the chemical analyses done in the lab are done with wet methods.

__5. The X-ray Fluorescence Spectrograph (XFS) is used to analyze only for free lime.

__6. X-rays are produced when inner electrons of atoms are disturbed.

__7. X-rays are produced when raw materials are heated in the kiln to 3000°F.

__8. The energy (frequency) of secondary X-rays produced in the XFS instrument tells how many protons are in the atoms giving off X-rays.

__9. By polishing and etching clinker samples, the kind and size of their crystals can be seen in a microscope.

__10. Compression strengths of cement-sand-water mixtures decrease as setting times increase.

IX. Organic Chemistry, Fuels

1. What is the older definition for organic compounds? _____

_____

_____

2. What is the newer definition for organic compounds?_____

_____ _____

_____ _____

3. Hydrocarbons are compounds made up of _____.

4. Draw the structural (ball and stick) formula for C_2H_6.

True or False.

___5. All organic compounds contain C, N, and Si.

___6. There are more organic compounds than inorganic compounds.

___7. The hydrocarbons are often used as fuels.

___8. Coal is an important source of organic compounds.

H

___9. The correct structural formula for propane is: H-C=C-C-H.

__10. All alcohols have an -OH functional group hooked to a carbon.

__11. Very few organic compounds will burn if heated.

Completion.

12. Organic compounds that burn produce the products _____ and _____.

13. The cement kiln provides a good environment in which to burn organic wastes because_____ _____.

14. Burning organic wastes at Holnam benefits Safety Kleen, Holnam, and the public because _____ _____.

15. What happens to metals in the waste materials being burned in the kiln? _____ _____.

ANSWER KEY

I. Basics

1. b
2. a
3. c
4. b
5. a.
6. b
7. c
8. b
9. a
10. a
11. c
12. metals and nonmetals
13. b
14. c
15. c
16. a
17. a
18. d
19. Classification (grouping) scheme for the elements.
20. Used to simplify working with a lot of information.
21. To help explain what we observe.

II. Metric

1. Advantages - simplifies and the rest of the world uses it. Disadvantages - cost money and time to change.
2. d
3. a
4. b
5. c
6. c
7. a
8. b

9. d
10. a

III. History

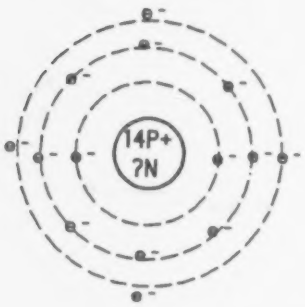
1. F
2. F
3. T
4. F
5. T
6. T
7. F
8. F
9. F
10. T

IV. Make-Up of Atoms

1. electrons, protons, neutrons
2. protons and neutrons are in the nucleus, electrons are outside the nucleus.
3. positive
4. protons
5.

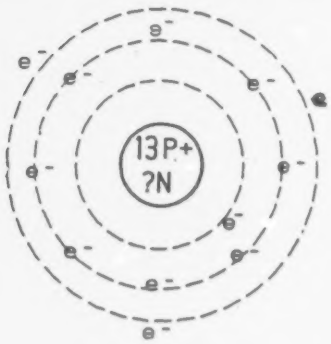
Lithium (Li) Atom

6. Silicon (Si) Atom

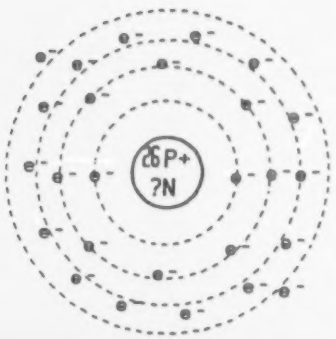


7. Hydrogen (H) atom

8. Aluminum (Al) Atom



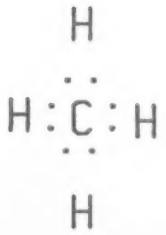
9. Iron (Fe) Atom



V. Bonding

1. b
2. a
3. a
4. b
5. b
6. a
7. CaO or $Ca^{+2}O^{-2}$
8. Na_2S or $Na^{+1}{}_2S^{-2}$
9. AlF_3 or $Al^{+3}F_3{}^{-1}$
10. $Ca(NO_3)_2$ or $Ca^{+2}(NO_3)_2{}^{-1}$
11. Fe_2O_3 or $Fe_2{}^{+3}O_3{}^{-2}$
12.

13.



14. They have 8 outer electrons, which is a stable number (except for helium with 2 outer electrons which is also a stable number).

VI. Solids, Liquids, Gases

1. b
2. c
3. a.

4. c
5. b
6. a
7. c
8. b (note: molecules keep moving in liquids).
9. c
10. d
11. a
12. d
13. c
14. b
15 a.

VII. Chemistry of Portland Cement

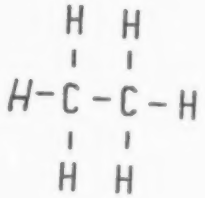
1. Limestone, clay (could also include iron oxide, coal.)
2. Coal, waste organics (occasionally fuel oil and natural gas).
3. limestone
4. clay
5. it decomposes into CaO and CO_2 (produces lime) (decarbonation).
6. Near a source of raw materials, and near a market for cement.
7. From the ocean (shells and skeletons of ocean creatures settled to bottom and compacted).
8. From the weathering of rocks and minerals.
9. Heating to a high temperature.
10. Lose the slurry water by evaporation, lose the combined water in clay, lose the CO_2 from the $CaCO_3$, make compounds like C_2S, C_3S, C_3A, C_4AF, partially melt, make clinker.
11. $3CaO \bullet SiO_2$ (or tricalcium silicate).
12. To control the setting time.
13. Reaction of the cement with water.

VIII. Control, Analysis, and Testing

1. To make sure the right proportions of ingredients are used.

2. lime (or quick lime, or calcium oxide)
3. T
4. F
5. F
6. T
7. F
8. T
9. T
10. F

IX. Organic Chemistry, Fuels

1. Compounds produced by living organisms.
2. Compounds are carbon.
3. Carbon and hydrogen.
4. 

5. F
6 T
7. T
8. T
9. F
10. T
11. F
12. carbon dioxide and water (CO_2 and H_2O)
13. High temperature and long burning distance
14. Saf-T Clean can get rid of waste organics, Holnam has an inexpensive fuel source, public doesn't have to worry about soil and water pollution.